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OCO (Orbiting Carbon Observatory) Project
OCO-2

Software Interface Specification for the SDOS Ephemeris Product

Revision A
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National Aeronautics and
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Change Log

Revision	Date	Sections Changed	Author
Initial	5/15/2014		C. Avis
A	11/18/2014	1, 4 (table entry deletions), 5 (comments), 6 (table entry deletions)	C. Avis

Table of Contents

1 Product Identification and Software Version

This document describes the specification of one of the data products generated by the OCO-2 Science Data Operations System (SDOS). This document applies to the following product and system version:

Product Name:	Ephemeris Product
Short Name:	OCO2_Eph
SDOS System Version:	B5.0.00
GES DISC Version:	Version 5
Product Description:	The position and velocity of the spacecraft for each orbit

2 Background information

The OCO-2 SDOS converts telemetry downloaded from the Observatory into data products that provide comprehensive mission results as well as material for further research and investigation. The SDOS generates products from Level 0 through Level 2, some of which are available for distribution to both the scientific community and the general public. All products are available to users of the SDOS computing cluster.

2.1 NASA Data Levels

The following table provides the definitions of the data levels used in this document. These definitions are standard within the NASA community

Level	Description
Packet data	Telemetry data stream as received at the ground station, with science and engineering data embedded
Level 0	Instrument science data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed
Level 1A	NASA Level 0 data that have been located in space and may have been transformed (e.g., calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied)

Level 1B	Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength)
Level 2	Geophysical parameters, generally derived from NASA Level 1 data, and located in space and time commensurate with instrument location, pointing, and sampling

2.2 Product Pedigree and Destination

This product is generated within the nominal SDOS pipeline by the AnE PGE using the following input data:

- APID 20 telemetry
- Orbit Boundary File

This product is expected to be an input to the following PGE's within the nominal SDOS pipeline:

- Geolocation PGE

2.3 Suggested Tools to Read Product

The following set of tools can be used to open and examine this HDF-5 product on Linux systems. Other tools may be available.

- h5dump
- hdfview.sh

3 Reference Documents

1. OCO-2 SDOS Software Design Document (JPL D-71459)
2. OCO-2 SDOS Data Bible v2.3 1/31/2014
3. OCO-2 Science Data Management and Archive Plan (JPL D-64039)

4 Product Description

4.1 Format and Size

This product is in HDF-5 format. For most nominal orbits, the product will use 2.9 megabytes.

4.2 Naming Convention

oco2_[*ProductId*]_[*Orbit*]_[*AcquisitionDate*]_[*ShortBuildId*]_[*ProductionDateTime*].h5

Field	Description	Format	Selection
ProductId	A mnemonic indicating a file type.	String	Ephem – Level 0 Ephemeris product
Orbit	The Orbit on which the associated data were acquired. If the Orbit number is less than 10,000, zeros are prepended to the number to ensure that the field is five digits long.	nnnnn	Actual Orbit number for data acquired during operations
AcquisitionDate	The date (UTC) the data were acquired.	yymmdd	

ShortBuildId	The identification of the related software build	B*stuu*	`s = ID of major build cycle`
			`t = ID of scheduled build within a major build cycle`
			`uu = ID of incremental or patch build`

ProductionDateTime	The date and time (UTC) that the file was produced.	yymmddhhmmss	

5 Specification Table

The HDF file structure consists of a large number of Data Elements with values. These Elements (a.k.a., 'fields') may be of various types (e.g., arrays, scalars) and are organized into Groups. Groups are utilized in various ways, such as to combine Elements/values generated by different PGE's.

Description of column headers in the following tables:

Data Element	The name of the Data Element
Shape	See Appendix 1
Type	The data type of the values
Units	The SI units of the values, if any
Minimum value	The lowest possible value. In some cases, this is the lowest safe value (i.e., a 'red' limit)
Maximum value	The highest possible value. In some cases, this is the highest safe value (i.e., a 'red' limit)
Comments	Descriptive information about the Element
(no value = n/a)	

L0_Ephemeris Product HDF specification

Group	**Metadata**					
Group description	Granule-level Metadata					
Data Element	**Shape**	**Type**	**Units**	**Minimum value**	**Maximum value**	**Comments**
Standard Metadata	See OCO-2 Standard Metadata specification table below					
EquatorCrossingLongitude	Scalar	Float32	Degrees	-180	180	The longitude of the equator crossing of the spacecraft ground track in the descending direction
EquatorCrossingTime	Scalar	String				The time of the equator crossing of the spacecraft ground track in the descending direction
EquatorCrossingDate	Scalar	String				The date of the equator crossing of the spacecraft ground track in the descending direction
AscendingEquatorCrossingLongitude	Scalar	Float32	Degrees	-180	180	The longitude of the equator crossing of the spacecraft ground track in the ascending direction
AscendingEquatorCrossingTime	Scalar	String				The time of the equator crossing of the spacecraft ground track in the ascending direction
AscendingEquatorCrossingDate	Scalar	String				The date of the equator crossing of the spacecraft ground track in the ascending direction
OrbitStartLongitude	Scalar	Float32	Degrees	-180	180	The longitude of the equator crossing of the spacecraft ground track in the descending direction

OrbitStartTime	Scalar	String				The time of the equator crossing of the spacecraft ground track in the descending direction
OrbitStartDate	Scalar	String				The date of the equator crossing of the spacecraft nadir track in the descending direction
OrbitEccentricity	Scalar	Float32				The eccentricity of the spacecraft orbital path
OrbitInclination	Scalar	Float32	Degrees	0	180	The angle between the plane of the spacecraft orbital path and the Earth equatorial plane
OrbitSemiMajorAxis	Scalar	Float32	Meters			The length of the semi-major axis of the spacecraft orbit
OrbitPeriod	Scalar	Float32	Seconds			The time span between two consecutive descending node crossings
EphemerisType	Scalar	String				The source of the spacecraft ephemeris data that were utilized to generate this data file
Group	**Ephemeris**					
Group description	Spacecraft attitude data at 1 Hz					
Data Element	**Shape**	**Type**	**Units**	**Minimum value**	**Maximum value**	**Comments**
time_string	EphemerisElement_Array	String				Date and time of the ephemeris measurement (yyyy-mm-ddThh:mm:ss.mmmZ)
time_tai93	EphemerisElement_Array	Float64	Seconds			Date and time of the ephemeris measurement in seconds since Jan. 1, 1993
x_pos	EphemerisElement_Array	Float64	Meters			X coordinate position of spacecraft
y_pos	EphemerisElement_Array	Float64	Meters			Y coordinate position of spacecraft
z_pos	EphemerisElement_Array	Float64	Meters			Z coordinate position of spacecraft
x_vel	EphemerisElement_Array	Float64	Meters Second^{-1}			X coordinate velocity of spacecraft
y_vel	EphemerisElement_Array	Float64	Meters Second^{-1}			Y coordinate velocity of spacecraft
z_vel	EphemerisElement_Array	Float64	Meters Second^{-1}			Z coordinate velocity of spacecraft
qual_flag	EphemerisElement_Array	UInt16				Bit flags indicating the quality of the ephemeris data: 0 - Good, non-zero - see Product Quality Flag table below

OCO-2 Standard Metadata

Group	Metadata					
Group description	This table describes the metadata contained in all OCO-2 HDF products					
	These metadata fields appear in the Metadata group in each of these products.					
	Each product may also contain product-specific fields in that group					
Data Element	**Shape**	**Type**	**Units**	**Minimum value**	**Maximum value**	**Comments**
AncillaryDataDescriptors	AncFile_Array	String				The file names of the ancillary data files that were used to generate this product (ancillary data sets include all input files except for the primary input files)
AutomaticQualityFlag	Scalar	String				Not implemented - set to NULL
BuildId	Scalar	String				The ID of build in which included the software that created this product
CollectionLabel	Scalar	String				Label of the data collection containing this product
DataFormatType	Scalar	String				'NCSA HDF' - A character string that describes the internal format of the data product.
GapStartTime	Gap_Array	String				The timestamp after which a nonexistent, unnecessary, spurious, questionable, or erroneous data segment begins. Set to 1993-01-01T00:00:00.000Z if no bad segment exists.
GapStopTime	Gap_Array	String				The timestamp before which a nonexistent, unnecessary, spurious, questionable, or erroneous data segment ends. Set to 1993-01-01T00:00:00.000Z if no bad segment exists.
GranulePointer	Scalar	String				The filename of this product
HDFVersionId	Scalar	String				'5.x' - A character string that identifies the version of the HDF (Hierarchical Data Format) software that was used to generate this data file
InputPointer	InputPtr_Array	String				A pointer to one or more data granules that provide the major input that was used to generate this product.
InstrumentShortName	Scalar	String				'OCO-2' - The name of the instrument that collected the telemetry data
LongName	Scalar	String				A complete descriptive name for the data type of this product
PlatformLongName	Scalar	String				'Orbiting Carbon Observatory 2'
PlatformShortName	Scalar	String				'OCO-2'
PlatformType	Scalar	String				'spacecraft' - The type of platform associated with the instrument which acquires the accompanying data
ProcessingLevel	Scalar	String				Indicates data level (Level 0, Level 1A, Level 1B, Level 2) in this product
ProducerAgency	Scalar	String				'NASA' - Identification of the agency that provides the project funding
ProducerInstitution	Scalar	String				'JPL' - Identification of the institution that provides project management.
ProductionDateTime	Scalar	String				The date and time at which the product was created (yyyy-mm-ddThh:mm:ss.mmmZ)
ProductionLocation	Scalar	String				Facility in which this file was produced, typically: 'Operations Pipeline', 'Operations Pipeline 2', 'Science Computing Facility', 'Test Pipeline', Test Pipeline 2'
ProductionLocationCode	Scalar	String				One-letter code indicating the ProductionLocation, typically: ' ' - Operations Pipelines (1) or 2, 's' - Science Computing Facility, 't' - Test Pipelines (1) or 2
ProjectId	Scalar	String				'OCO-2' - The project identification string
QAGranulePointer	Scalar	String				A pointer to the quality assessment product that was generated with this product

RangeBeginningDate	Scalar	String				The date on which the earliest data contained in the product were acquired (yyyy-mm-dd)
RangeBeginningTime	Scalar	String				The time at which the earliest data contained in the product were acquired (hh:mm:ss.mmmZ)
RangeEndingDate	Scalar	String				The date on which the latest data contained in the product were acquired (yyyy-mm-dd)
RangeEndingTime	Scalar	String				The time at which the latest data contained in the product were acquired (hh:mm:ss.mmmZ)
ShortName	Scalar	String				The short name identifying the data type of this product
SISName	Scalar	String				The name of the document describing the contents of the product
SISVersion	Scalar	String				The version of the document describing the contents of the product
SizeMBECSDataGranule	Scalar	Float32	Megabytes			The size of this data granule in Megabytes
StartOrbitNumber	Scalar	Int32		1	99999	The first orbit on which data contained in the product were acquired
StartPathNumber	Scalar	Int32		1	233	The first WRS path on which data contained in the product was collected
StopOrbitNumber	Scalar	Int32		1	99999	The last orbit on which data contained in the product were acquired
StopPathNumber	Scalar	Int32		1	233	The last WRS path on which data contained in the product was collected

Product Quality flag

qual_flag	Bit
Incomplete Ephemeris Data, 0=data complete, 1=not complete	0
Ephemeris Packet Length Error, 0=packet length is as expected, 1=not expected length	1
Nominal Time Interval, 0=standard time interval between packet and previous packet, 1= time interval not within expected range	2
Long Time Interval, 0=time interval between current packet and previous good packet does not indicate a data gap, 1=time interval long enough to constitute a data gap	3
Suspect Time Interval, 0=time interval between current packet and previous good packet will not impact geolocation accuracy, 1 = time interval long enough to impact geolocation accuracy	4
Spare	5-15

6 Appendix 1: Shape Descriptions

The shape name of a data element is a descriptive label that describes the rank and dimensions of that element.

Rules for creating shapes:

1. Shape names do not include any context information, such as what mode the instrument is in when it takes data with that shape. Any context information needed to distinguish between similarly named dimensions is appended as a label, just before the "_Array" suffix.
2. Any "temporal" dimension, e.g. Frame, is always outermost.
3. If Frame and Sounding are both present, they occur in direct sequence, i.e. Frame_Sounding_.
4. Shapes that include Frame, Sounding, and Spectrum cannot have any additional dimensions.
5. Spectrum precedes all other physical instrument dimensions, except when this rule contradicts any of the above rules.
6. If Spectrum and Sounding are present in the absence of Frame, they occur in direct sequence, i.e., Spectrum_Sounding.
7. Color comes after SinglePixel.
8. SinglePixel comes after Slice.

Shape	Rank	Max dimension sizes (Units)	Dimensions
AncFile_Array	1	20 (Number of ancillary input files)	AncFile
EphemerisElement_Array	1	6081 (Packets)	EphemerisElement
Gap_Array	1	10 (Number of gaps)	Gap
InputPtr_Array	1	20 (Number of primary input files)	InputFile

7 Appendix 2 – Acronyms

APID	Application Process Identifier
ASCII	American Standard Code for Information Interchange
ASD	Algorithm Specification Document
ATBD	Algorithm Theoretical Basis Document
CO_2	Carbon Dioxide
DAAC	Distributed Active Archive Center
DOORS	Dynamic Object Oriented Requirements
ECHO	Earth observing system Clearing HOuse - The NASA-developed spatial and temporal metadata registry
ECMWF	European Center for Medium-range Weather Forecast
EDOS	EOS Data and Operations System
EOS	Earth Observing System
GES DISC	Goddard Earth Sciences Data and Information Services Center
HDF	Hierarchical Data Format
HECC	High-end Computing Capability
ICD	Interface Control Document
IMAP-DOAS	Iterative Maximum A Posteriori Differential Optical Absorption Spectroscopy
IOC	In-Orbit Checkout
ITAR	International Traffic in Arms Regulations
MOS	Mission Operations System
MOU	Memorandum of Understanding
NAS	NASA Advanced Supercomputing
NASA	National Aeronautics and Space Administration
O_2	Oxygen
OCO	Orbiting Carbon Observatory
PGE	Product Generation Executive
SCF	Science Computing Facility
SDOS	Science Data Operations System

SIS	Software Interface Specification
SP4A	Simple, Scalable Script-based Science Processor Archive
TBD	To Be Determined
TCCON	Total Carbon Column Observing Network
UTC	Coordinated Universal Time
X_{CO2}	Column-averaged dry air mole fraction of atmospheric CO_2